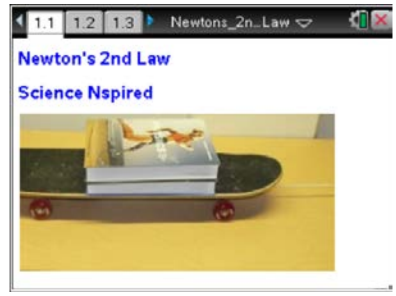


Science Objectives

- Students will explore a simulation of Newton's 2^{nd} Law.
- Student will collect mass, force, and acceleration data in a simulation.
- Students will analyze data to develop and apply Newton's 2^{nd} Law.

Vocabulary

- acceleration
- force
- frictionless
- mass
- Newton's Laws

About the Lesson

- This lesson simulates the acceleration of a frictionless cart being pulled by a steady force.
- As a result, students will:
  - Manipulate values for force and masses in different situations.
  - Measure acceleration and capture data.
  - Plot and analyze data to develop Newton's 2^{nd} Law.
  - Apply Newton's 2^{nd} Law to solve problems.

TI-Nspire™ Navigator™

- Send out the *Newtons_2nd_Law.tns* file.
- Monitor student progress using Screen Capture.
- Use Live Presenter to spotlight student answers.

Activity Materials

- *Newtons_2nd_Law.tns* documents
- TI-Nspire™ Technology

TI-Nspire™ Technology Skills:

- Download a TI-Nspire document
- Open a document
- Move between pages
- Use minimized sliders
- Capture data
- Plot data & analyze plots

Tech Tips:

Slider use:

- go to a page with sliders
- tab until slider is selected and enter to active slider
- use arrow keys to change values or just type value
- esc esc to release slider

Lesson Materials:

Student Activity

- Newtons_2nd_Law_Student .doc
- Newtons_2nd_Law_Student .pdf

TI-Nspire document

- Newtons_2nd_Law.tns

Discussion Points and Possible Answers

Move to pages 1.2–1.4.

Have students answer the questions on either the handheld, on the activity sheet, or both.

Q1. In the photo (page 1.1) is a frictionless cart on a smooth table. A constant horizontal force is being applied to the right. What will happen to the cart when it is released?

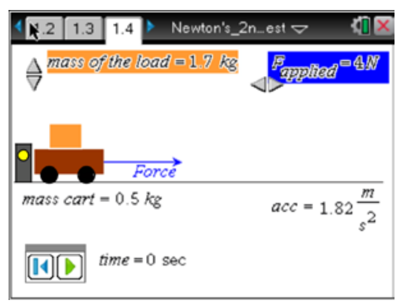
Answer: B. It will move to the right at increasing speed.

Q2. On the next page is a simulation of a cart on a table. Press the start animation button and see that the cart does accelerate to the right. The accelerometer displays the value of the cart's acceleration. What happens if you change the applied force?

Answer: A. More force gives more acceleration.

> **Tech Tip:** If students tab too often, the Entry Line may appear at the bottom of the screen. Press ctrl G to hide it. To hide the chevron, move the cursor over the chevron and press ctrl menu **> Hide Chevron.**

Move to page 1.5.



1. To explore the relationship between the force and the acceleration, go back to the simulation page (1.4). Change the load to whatever you wish, but do not change it for the rest of the experiment. Note the mass of the cart and load. Press ctrl . to capture the current data of force and acceleration in a spreadsheet on page 1.7.
2. Change the force to another value, note how the acceleration value changes, and capture the new data by again pressing ctrl . . Repeat this over a wide range of forces. The animation does not need to be active.

> **Tech Tip:** Students will collect data by pressing ctrl . each time they change a value in the experiments. The data will automatically appear in a spreadsheet on a later page and they can be plotted and analyzed on yet another page in the .tns document.

Move to pages 1.6–1.9.

3. After you have captured many data values, have a look at the spreadsheet on page 1.7. It is difficult to see a relationship in just a list of values, so then move to page 1.8 and plot **force** versus **accel**. Analyze this plot to find the relationship.

Move to pages 1.9–1.13.

Have students answer the questions on either the handheld, on the activity sheet, or both.

Force is measured in newtons (N). $1\,N = 1\,kg * \frac{m}{s^2}$

The slope units can therefore also be expressed as $\frac{kg*\frac{m}{s^5}}{\frac{m}{s^2}} = kg$

> **Teaching Tip:** Spend a few moments to help students understand the complex newton unit.

Q5. What is the slope of the **force** versus **accel** graph?

__Answer__: The slope will be equal to the mass of the cart + the load = total mass.

Q6. What are the units of the slope?

__Answer__: kg

Q7. What quantity does the slope represent?

__Answer__: total mass of the system (cart + load)

Q8. What quantity does the **y-axis** represent?

__Answer__: force (F)

Q9. What quantity does the **x-axis** represent?

__Answer__: acceleration (a)

> **Teaching Tip:** This same process of using the real quantities in the linear equation will be used for each part, so take the time to make students familiar with it. Also note the y-intercept value.

Q10. Rewrite the equation for your linear plot substituting the actual quantity symbols represented by *y*, *x*, and slope. This is equation is known as __Newton's 2nd Law__.

__Answer__: $y = mx + b$ ($b = 0$)

Force = mass of system × acceleration or F = m × a

TI-Nspire Navigator Opportunities

Use TI-Nspire Navigator Screen Capture to show different graphs from different students, but still having a slope equal to the mass set by the student. F = ma applies in each case.

Problem 2: Acceleration and Mass

For this experiment students will vary the mass and measure the acceleration of the cart with constant force.

> **Teaching Tip:** The next part is the same as the last, except that students set a fixed force and vary the load (mass 0f the system).

Move to page 2.1.

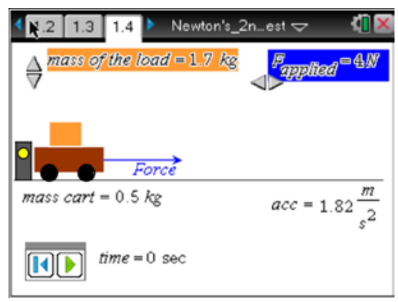
Have students answer the question on either the handheld, on the activity sheet, or both.

Q11. What happens to the cart if the force is kept constant but the load increases?

Answer: B. More load means less acceleration.

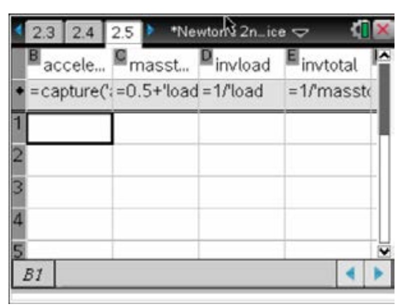
Move to pages 2.2–2.6.

4. The next page shows the cart again. Set the force to any convenient value and note that value. Do not change the force again throughout this part of the experiment. Now note the mass, load, and acceleration. Press [ctrl] [.] to collect this data. Change the load, observe the new acceleration and again collect the data with [ctrl] [.]. Repeat this over a wide range of loads. The animation does not need to be active. Observe the collected data on the next page. On page 2.6, plot:
   - **acceleration** versus **load**, and
   - **acceleration** versus **masstotal**.



Move to pages 2.7–2.8.

5. None of your plots should appear linear. Their general shape suggests an inverse relation. Go back to the data page (2.5). Name column D **invload** and enter the formula =**1/load** in the formula cell under the title. Name column E **invtotal** and enter the formula =**1/masstotal** in the formula cell. Then move to page 2.8.



Move to page 2.9.

6. On page 2.9, plot:
   - **acceleration** versus **invload**, and
   - **acceleration** versus **invtotal**.

   Find the linear relationship for the one that is most linear.

Move to pages 2.10–1.12.

Have students answer the questions on either the handheld, on the activity sheet, or both.

Q15. What is the slope of the linear equation with units?

<u>Answer</u>: slope will equal value of applied force in kg*m/s^2 or N

Q16. What does the slope represent?

<u>Answer</u>: slope represents force applied to cart (F)

Q17. Rewrite the equation for your linear plot substituting the actual quantity symbols represented by *y*, *x*, and slope. How does this equation compare to Newton's 2nd Law?

<u>Answer</u>: $y = mx + b$ (b= 0, y is accel, x is invtotal or 1/mass total, slope is force)
acceleration = force × 1/mass or $a = F/m$ This is a rearrangement of Newton's 2nd Law.

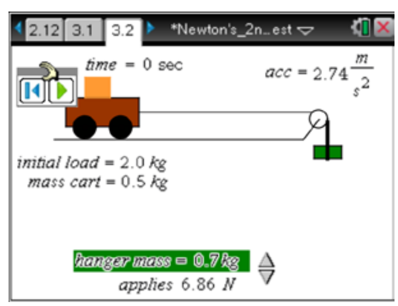
Q18. When using Newton's 2nd Law, what is important to remember about the mass?

<u>Answer</u>: use total mass of system

Problem 3: Acceleration and Mass of System

For this experiment you will vary the force provided by a hanging mass and measure the acceleration of the cart. You will keep the system mass constant.

Move to pages 3.1 and 3.2.



7. Now we will change the system a little. The force will be provided by a weight hanging over a pulley on the edge of the table. You can change the applied force by adding mass to the hanger (with the slider). There is a slight problem with just adding mass to the hanger. We need the mass of the system to remain constant, so we transfer mass from the load on the cart to the hanger. (Note the load will change as you change the mass on the hanger.)

Teaching Tip: Discuss what adding new mass to the hanger does to the force and the total mass (changing two variables at once: force and total mass). Help students explain how transferring mass solves the problem.

Move to page 3.3.

Have students answer the question on either the handheld, on the activity sheet, or both.

Q20. Why must we transfer mass between the cart load and hanger and not just take mass from the table to the hanger (or from the hanger to the table)?

Answer: keep total mass of system constant

Move to pages 3.4–3.6.

8. On the simulation on page 3.2, note the mass of the cart, the initial mass of the load, the initial mass of the hanger, and the acceleration. Also note the force applied is the weight of the hanger = mass hanger × g. Capture the initial data with [ctrl] [.]. Increase the applied force by increasing the mass on the hanger with the slider. Capture a new set of data. Repeat over a wide range of hanger masses.
9. On page 3.6 is the spreadsheet of captured data showing acceleration, applied force, hanger mass, load mass and total mass. Move to page 3.7 and explore various plots to get a meaningful linear relationship and find the equation.

Move to pages 3.7 and 3.8.

Have students answer the questions on either the handheld, on the activity sheet, or both.

Q22. Record the equation here.

> **Teaching Tip:** There are several linear plots; some are vertical or have negative slope. Consider the units of the slope. The easiest to use is force versus acceleration to give a slope having units of kg (and equal to total mass).

Q23. Rewrite the equation for your linear plot substituting the actual quantity symbols represented by *y*, *x*, and slope.

Answer: *y* is force; *x* is acceleration; slope is total mass
Force = total mass × acceleration or F = *ma*

TI-Nspire Navigator Opportunities

Use TI-Nspire Navigator Screen Capture to show different plots from different students and compare the linear equations.

Tech Tip: Once an analysis is done on a plot, plots can be changed and a new analysis best fit automatically shows for the new plot.

Move to page 4.1.

Problem 4: Apply Newton's 2nd Law

10. On the next several pages are some applications of Newton's 2nd Law. Calculate the needed values and provide the answer with the correct units. Use Scratchpad for the calculations, or do them on separate paper.

Move to pages 4.2–4.5.

Have students answer the questions on either the handheld, on the activity sheet, or both.

Q25. A 0.5 kg ball is dropped from a bridge and accelerates downwards at 9.8 $m/^{s2}$. What force is making it accelerate?

<u>Answer</u>: F = ma = 4.9 N

Q26. A 40 kg go-cart is being driven by a 60 kg driver. The cart can accelerate at 1.2 m/s^2. What force does the ground exert through the wheels to produce this acceleration?

<u>Answer</u>: F = ma = 120 N

Q27. What acceleration would a 200 N force cause on a 50 kg mass that was able to move freely?

<u>Answer</u>: a = F/m = 4 m/s^2

Q28. A hanger has a mass of 0.80 kg and pulls on a string attached to a 0.60 kg frictionless cart carrying a load of 1.6 kg. What acceleration would we expect the cart to have?

<u>Answer</u>: $a = F/m_{total} = (m_{hanger} \text{ x } g)/(m_{hanger} + m_{cart} + \text{load}) = 2.6\ m/s^2$

Extension

For students familiar with calculus, applying Newton's 2nd Law to a rocket launch can be very interesting. As the fuel burns and is ejected to provide thrust (force), the mass decreases, causing a change in acceleration. Knowing the rate of fuel use allows the calculation of the rate change of acceleration. See Science Nspired activity: "NASA Shuttle Ascent". Go to education.ti.com/exchange and search on keyword "16970" to find this activity.

TI-Nspire Navigator Opportunities

Use TI-Nspire Navigator Screen Capture to monitor student progress and to retrieve the file from each student at the end of the class period. Many of the student questions can be electronically graded and added to the student portfolio. During the lesson, Screen Capture can be used to illustrate example student work as a focus for discussing concepts or difficulties.

Wrap Up

Have students explain what each quantity in Newton's 2nd Law means and how they relate to a real situation. Explain that this is idealized (frictionless) and encourage students to give ideas of how this applies to real situations. Have students provide and explain real situations (sports, extreme transport, interesting travel modes…).

Assessment

- Formative assessment will consist of questions embedded in the .tns file. The questions can be graded when the .tns file is retrieved. The TI-Nspire Navigator Review features can be utilized to give students immediate feedback on their assessment.
- Summative assessment may consist of questions/problems on a chapter test, or a graded report on Newton's Laws in the Real World.